Quantitative relationship between potato tuber damage and counts of Pacific coast wireworm (Coleoptera: Elateridae) in baits: seasonal effects

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ABSTRACT

Experimental plots of potatoes were baited with rolled oats in spring to assess the relationship between counts of Pacific coast wireworm, *Limonius canus* (Coleoptera: Elateridae), and end-of-the-season damage to potato tubers. Baiting was done at seven intervals beginning before planting of potatoes and ending following plant emergence. Injury (percentage of tubers damaged or number of holes per tuber) showed a curvilinear relationship with increasing wireworm counts in baits. Damage increased rapidly with increasing wireworm numbers at lower densities, eventually flattening out at very high counts. Wireworm counts in baits fluctuated seasonally, increasing from lows obtained during pre-planting samples to a peak just before plant emergence, followed thereafter by declines in counts. Thus, baiting efficiency varied seasonally. Low counts in baits during the pre-planting interval may have been due primarily to low soil temperatures, while declining counts following plant emergence may have been due to the presence of competing food sources (i.e., the seed piece and developing potato plant). I also assessed depth of wireworms in the soil profile between late-March and mid-May, and found that a relatively large percentage (approaching 25% on two dates) of wireworms occurred very deep in the soil (61-91 cm) until soil temperatures at 31 cm approached 17 °C in early- to mid-May. Thus, low counts in baits during the pre-planting samples may also have occurred in part because a proportion of the population was deep in the soil during this time interval. Seasonal variation in baiting efficiency led to date-to-date differences in predicted damage for a given wireworm count. Low efficiency during the pre-planting interval would complicate efforts to use pre-planting baiting as a means to predict end-of-the-season tuber damage.

Key Words: *Limonius canus*, potato, sampling, damage prediction, spatial distribution

INTRODUCTION

The Pacific coast wireworm, *Limonius canus* LeConte (Coleoptera: Elateridae) is an important pest of potatoes in the major potato growing regions of central Washington State. Problems caused by wireworms in potatoes and other crops appear to be increasing in severity (Jansson and Seal 1994, Parker and Howard 2001, Alvarez 2004), for unknown reasons. Several factors complicate efforts to manage these pests, including incomplete understanding of adult and larval field biology, multi-year development times, and a paucity of effective chemicals (Parker and Howard 2001, Alvarez 2004).

A lack of efficient tools with which to estimate wireworm densities has also complicated efforts to manage these pests in potatoes (Jansson and Seal 1994, Parker 1996, Parker and Howard 2001, Alvarez 2004), to the extent that most potato growers who apply insecticides for controlling wireworms likely do so without having first sampled for these pests. Wireworms are monitored either by taking soil cores or by burying some type of bait. Unfortu-

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nately, these pests have a number of characteristics that have limited the use of either sampling method in potatoes. Those characteristics include patchy spatial distributions (Onsager 1969, Williams *et al.* 1992), a tendency to cause damage even at very low and often undetectable densities (Parker and Howard 2001), and their seasonal movement vertically through the soil profile (Jones and Shirck 1942). Additional complications arise because it is not known what levels of damage can be expected for a given absolute density of wireworms in a potato field (Parker and Howard 2001).

A number of studies have shown that food baits (e.g., germinating grain seed, rolled oats, seedling grains) can be used to attract or sample wireworms (Apablaza *et al.* 1977, Toba and Turner 1983, Jansson and Lecrone 1989, Parker and Howard 2001, Horton and Landolt 2002, Vernon *et al.* 2003). However, attempts to use baiting for estimating damage potential or for predicting damage to harvested tubers have shown inconsistent success (Parker 1996, Parker and Howard 2001). One factor that might affect whether baiting in spring can be used to predict end-of-season damage to tubers is timing of baiting relative to seasonal phenology of the pest. Specifically, wireworms move down the soil profile in autumn in preparation for overwintering, returning towards the soil surface in early spring as soil temperatures warm (Jones and Shirck 1942, Lafrance 1968). Baiting trials that are done once most wireworms have moved near the soil surface would seemingly provide a better index of wireworm density and have higher predictive value than trials done earlier in the year when the insects are deeper in the soil and potentially too far away from the baits to respond to the attractants. Soil treatments for wireworms in potatoes are done before or at planting, thus if baits are to be used for determining whether treatment is necessary, baiting in spring must be done very early in the season. At that time of year, an unknown (but potentially significant) proportion of the population could be relatively deep in the soil. If this is true, baiting in spring could provide changing estimates of damage potential through time even within one field, just due to movement by wireworms towards the soil surface as the season progresses.

Objectives of this study were to examine the relationship between pre- and post-planting counts of *L. canus* in baits and end-of-year tuber damage, and to assess whether the relationship between counts and damage changes through time. I also examined the depth of *L. canus* in the soil profile between March and May, to assess whether any seasonal variation in baiting efficiency might be explained partially by phenology of wireworm movement upwards into the baiting area from overwintering quarters deeper in the soil.

MATERIALS AND METHODS

Study site. The studies were done in a field at the USDA-ARS experimental farm located near Moxee, Washington. The soil type is a sandy loam. The field has been used exclusively for small plot trials with potatoes for at least the five years preceding this study. Soil insecticides were not used in the current trials or in previous years. The field has a history of infestation by Pacific coast wireworm, based upon examination of adults and larvae collected from the field during the study and in previous years. Wireworm species other than *L. canus* are only rarely collected in the study field. Vouchers of larvae collected from the study site are in the collection of the author.

Baiting trial (2004). Thirty plots were established on 12 April 2004, two weeks preceding planting of potatoes. Each plot was 10 rows wide by 10 m in length, separated from adjacent plots by 10 m of bare soil. Baiting began on 16 April, before planting. Potatoes (Russet Burbank) were planted on 26 April at 0.3 m spacing within rows. Irrigation was done using overhead sprinklers. Arthropod pests were not controlled, other than an application of a pyrethroid insecticide (Asana) in summer to control Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae). Weeds were controlled using a pre-planting application of trifluralin (Treflan) and an application of metribuzin (Sencor) at layby. Temperature of the soil at 31 cm was monitored using two Hobo temperature recorders (Onset Computer Corporation, Bourne, MA), buried in two of the plots.

Baits composed of uncooked rolled oats (Quick Oats; Western Family, Portland, Oregon) were used to sample wireworms (Horton and Landolt 2002). Bait ingredients were a 2:1 (by volume) mix of potting soil and rolled oats. The potting soil was a 1:1:1 (by volume) mix of sand, peat, and vermiculite. This particular mix was used because it was readily available from the plant-rearing operations at our laboratory. An individual bait was composed of ca. 120 ml of the soil and rolled oats mixture, wrapped in a 25 x 25 cm section of 3 x 3 mm bridal veil mesh. Mesh size was large enough to allow wireworms to enter the bait, but was small enough to contain the bait. A section of bright colored twine was attached to each bait, to allow easy retrieval from the field. Baits were thoroughly saturated with water just before they were buried in the plots. Baits were buried between the potato rows, 20-25 cm in depth.

Plots were baited weekly for six consecutive weeks beginning on 16 April; a seventh sample was taken 22 June, well after plant emergence. The first two samples (20 and 26 April) were collected before planting. In every sampling week, baits were left in the ground for four days. After the four-day interval, baits were retrieved and examined in the field. Wireworms were counted, categorized to size ($\leq$ 1 cm or > 1 cm), and then returned immediately to the hole from which the bait was retrieved. Wireworms were returned to the soil to ensure that the baiting itself did not substantially affect absolute population densities in the plots. By examining the baits in the field, it is possible that some very small wireworms were missed and not counted. However, examination of baits in the field allowed me to process a large number of baits and to return wireworms immediately to the plots from which they had been collected, so this method of sampling was used.

A very high density of baits (9 per plot) was used, to maximize chances of obtaining good regressions relating wireworm counts and tuber damage. Bait density is too high to be used realistically by growers, but objectives of the study are to understand phenological aspects of the baiting process, and not to develop here a grower-friendly monitoring tool. The density of nine baits per plot was used in 25 of the 30 plots. The remaining five plots each contained a single bait, to provide a few preliminary data about whether bait density might affect prediction. The data from the five plots having the low bait density are not used in the following analyses, but are shown in the figures. The nine baits in the 25 plots that had the high bait densities were set out in 3 x 3 grids, with approximately three m spacing between baits, and two m between plot edges and baits. In the five plots having one bait per plot, the bait was placed near the center of the plot. Bait positions were shifted laterally 0.3-1.0 m between sample weeks, either within the same row or to an adjacent row. By shifting location, I avoided damaging just-released wireworms (collected in the newly recovered baits) as I excavated the holes into which the new baits were to be placed.

Tubers were harvested in late September from rows 3, 5, 6, and 8 (of the 10 rows) in each plot. Harvest excluded the two plants at either end of each row. I randomly selected 400 tubers per plot from the four harvested rows. The samples included all tuber sizes. Tubers were washed, and then examined for wireworm damage. Tuber damage was expressed as percentage of tubers having wireworm injury and as number of wireworm holes per tuber.

Linear and non-linear regression was used to assess the relationship between wireworm counts in baits and tuber damage. Only data from the plots that were baited with nine baits per plot are used in the regressions (N = 25 observations per regression). The models were fitted in the graphics package SigmaPlot (Systat Software, Richmond, CA).

Depth in the soil profile (2005). Phenological trends in the baiting data from 2004 (see Results) suggested that it would be worthwhile to examine how vertical distribution of wireworms in the soil changed through time during the March-May baiting period. In spring 2005, distribution of wireworms at three depths was examined: 0-31 cm, 31-61 cm, and 61-91 cm. The samples were taken in the same field used in the 2004 baiting study. The field was left fallow during the 2005 study.

I extracted 31 cm long cores of soil using a soil auger (91 cm long x 15 cm in diameter) attached to a tractor. A 61 x 61 cm square of plywood having a 20 cm diameter hole cut in the center was used as a guide for the auger. The guide was placed flat on the soil surface at a randomly located spot in an area of the field known to have wireworms. The auger was then lowered through the 20 cm hole until it reached a depth of 31 cm. As the auger was extracted, the excavated soil fell onto the plywood square. Loose soil falling back into the hole was scooped out by hand. The plywood guide was removed from the cored area, and a second guide was placed over the newly drilled hole. The auger was then lowered to the 61 cm depth, and the soil was again excavated and deposited on the plywood guide. The process was repeated a third time to obtain the 61-91 cm depth sample. Excavated soil on the guides was examined in the field for wireworms. Wireworm size was not recorded. Thirty to sixty cores per sampling date were examined. With this volume of soil examined, it is likely that some very small wireworms were missed and not counted. A Hobo data logger was used to monitor soil temperature at 31 cm.

RESULTS

Baiting trial (2004). Counts in baits indicated that wireworms were distributed non-uniformly among the 30 plots (Fig. 1A). Numbers of wireworms summed over the seven sampling dates varied among plots between 0 and 54.1 per bait. In four plots, baiting failed to collect a single wireworm over the duration of the sampling study (Fig. 1A: plots lacking black squares). Wireworm numbers in baits changed seasonally (Fig. 2). Counts averaged 1.0 wireworms per bait on the first sample date, increasing to a peak of 3.3 per bait just before plant emergence (17 May), and dropping thereafter (Fig. 2). A maximum of 17.4 wireworms per bait was obtained in one plot on the 17 May sampling date. Percentage of wireworms that were 1 cm or less in length varied among the seven sampling dates between 34% and 66%, with the highest percentage value occurring in the 22 June sample.

Tuber damage was highly variable among plots (Figs. 1B-C). Percentage of tubers damaged varied between 3% and 89% (Fig. 1B), whereas number of holes per tuber varied between 0.05 and 6.4 (Fig. 1C). Damage was seen in all plots, including in those four plots from which no wireworms were collected during the seven baiting intervals.

The relationship between percent of tubers damaged and counts in baits was curvilinear (Fig. 3). An asymptotic model was fitted:

% damage = Intercept + a*(1-exp(-b*wireworms per bait)).

The b-term describes how rapidly the asymptote is approached; the asymptote is the sum of the a-term and the intercept term. Based upon r^2 values, models of this form consistently fit the data better than linear, quadratic, or power models. The regressions were fitted to data from the 25

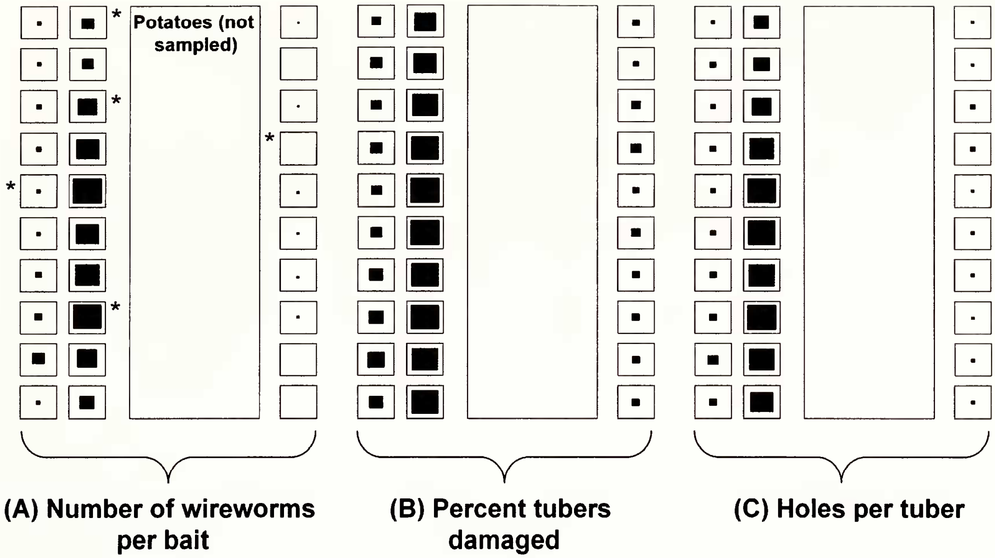

Figure 1. Arrangement of the 30 study plots (each 10 rows wide x 10 m long) on two sides of an unsampled potato field. Area of the black square within any plot is proportional to number of wireworms per bait summed over the seven sampling dates (Figure A: range 0 to 54.1 wireworms per bait), percentage of tubers damaged (Figure B: range 3% to 89% tubers damaged), or number of holes per tuber (Figure C: range 0.05 to 6.4 holes per tuber). The four plots in which no wireworms were collected in baits lack black squares (Figure A). Asterisks in Figure A show location of the five plots that received one bait per plot.

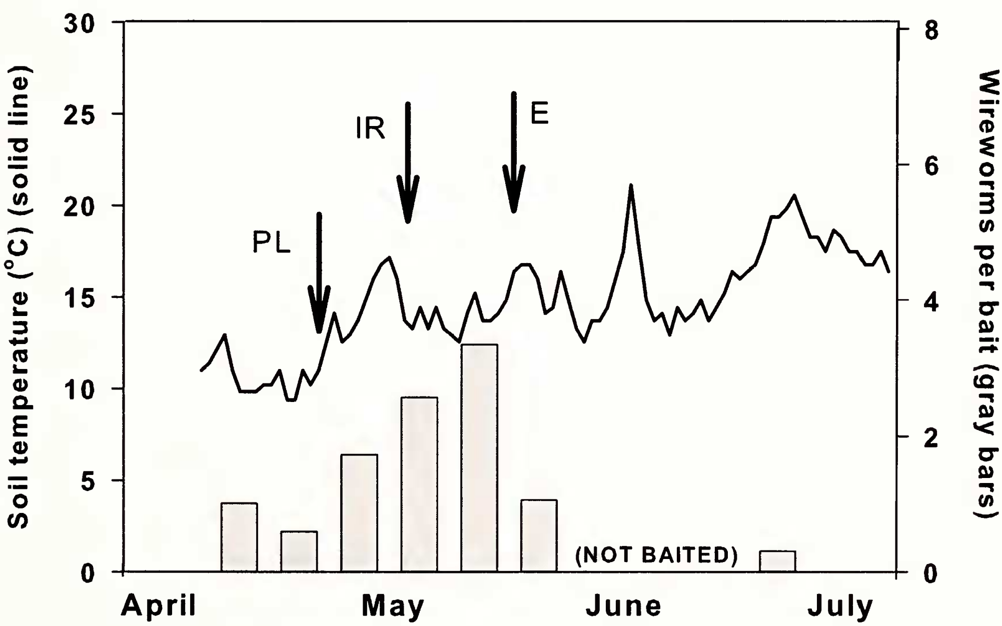

Figure 2. Soil temperature at 31 cm (solid line) and wireworm counts per bait (gray bars) over the duration of the baiting study. Collection dates for baits: 20 April, 26 April, 3 May, 10 May, 17 May, 24 May, and 22 June. Arrows show date of planting (PL), first irrigation (IR), and plant emergence (E).

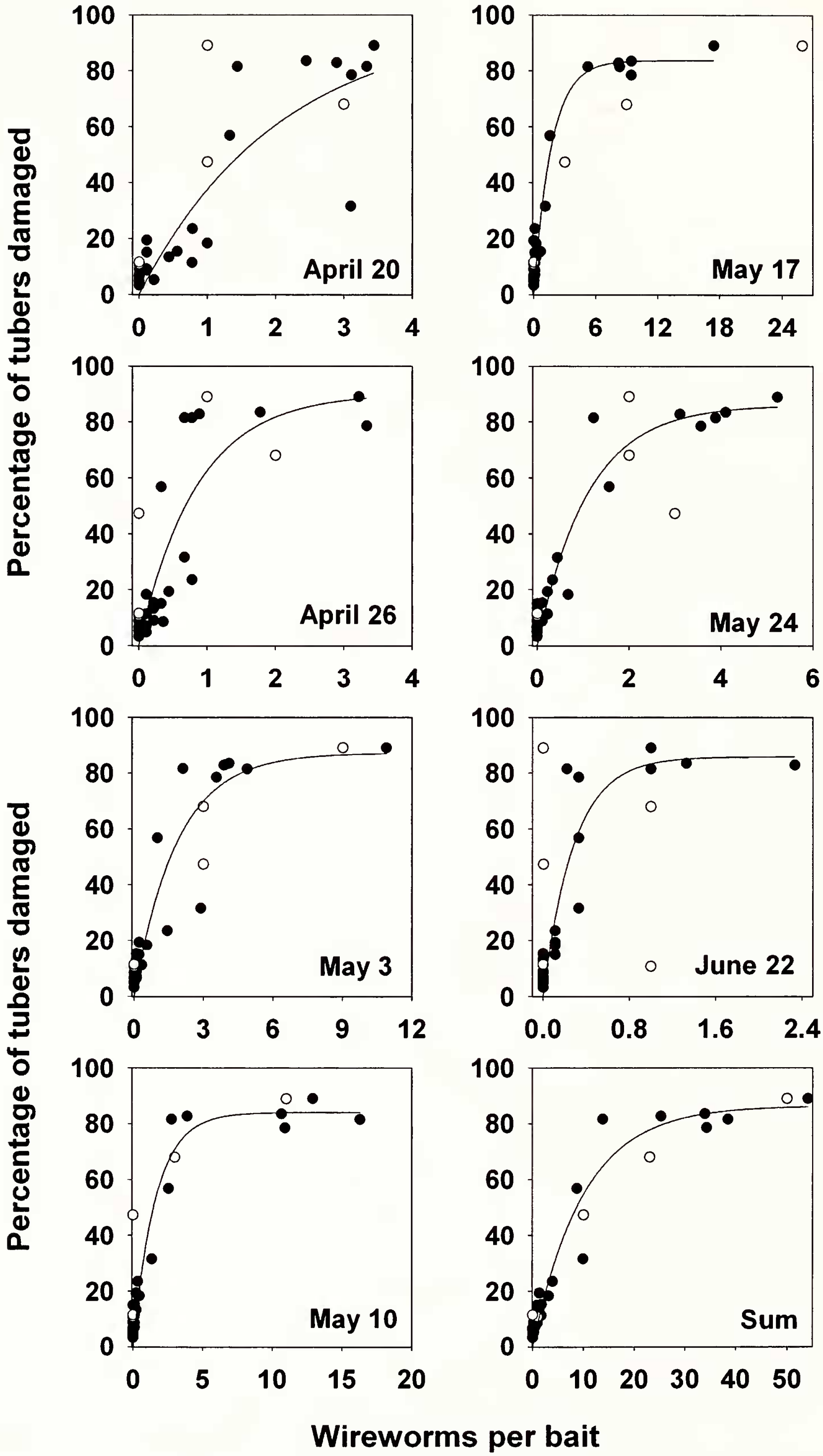

Figure 3. Scatter plots and regression lines showing relationship between number of wireworms per bait and percentage of tubers damaged. Solid circles: nine baits per plot (N = 25 plots); open circles: one bait per plot (N = 5 plots). Regressions fitted excluding the open symbols. "Sum": wireworm numbers per bait were summed over the seven sample weeks.

plots having nine baits per plot (filled symbols in Fig. 3), although data for the five plots having one bait per plot are shown (as open symbols in Fig. 3). Except for the 20 April sample, predicted damage approached an asymptote at 85-92% of tubers, irrespective of sampling date (Fig. 3; regression coefficients are reported in Table 1). The r^2 values were lowest for the two pre-planting sample dates (Table 1).

Both linear and curvilinear models were fitted to describe the relationship between number of holes per tuber and wireworm counts (Fig. 4). An asymptote model of the same form used to describe percentage damage again fit the data better than a linear model (Fig. 4; see Table 2 for r^2 values), and also fit the data better than a quadratic or power model (data not shown). Data for the five plots having a single bait per plot (open symbols in Fig. 4) often fell well away from the scatter of points for the data obtained in the other 25 plots (filled symbols in Fig. 4), suggesting that bait density may affect fit of models quite substantially. For the asymptote model, r^2 values were again lowest for the two pre-planting sampling dates (Table 2).

Predictions of percent damage (from the asymptote models in Figure 3) for a given density of wireworms depended upon when the sampling was done (Table 3). For example, at a count of 1.0 wireworms per bait, damage was predicted to be 62% of tubers for the 26 April sampling date, dropping to 35-38% for the early- and mid-May samples, and then increasing to 49% in late May and 83% in June (Table 3). Predictions of damage generally were higher (for a given bait count) during those weeks when overall counts in baits were lowest.

Depth in the soil profile (2005). Numbers of wireworms collected in the soil cores varied from 37 to 51, depending upon sample date (Table 4). The results suggest that movement up the soil profile in spring occurred over a relatively long time period (Table 4). On two dates, almost a quarter of wireworms collected were obtained at the 61-91 cm depth. Only on the final sample taken 13 May did I fail to collect wireworms at the lowest depth. On that date, soil temperatures at 31 cm had reached 17 °C.

DISCUSSION

Baiting trials showed that wireworm densities (as reflected by counts in baits) and tuber damage were highly variable among plots (Fig. 1), suggesting that wireworms had a non-uniform distribution in the field (Onsager 1969). Environmental or biological factors leading to these non-uniform distributions of *L. canus* and dam-

Table 1.
Regression statistics from asymptote models relating wireworm counts per bait and percentage of tubers damaged. N = 25 observations per date.

Sample date	Intercept	*a*	*b*	r^2
20 April	4.7[1]	104.5	0.37	0.80
26 April	1.6[1]	89.1	1.13	0.75
3 May	6.1[1]	85.7	0.43	0.87
10 May	6.8	78.2	0.51	0.97
17 May	7.9	77.3	0.43	0.97
24 May	6.8	81.9	0.73	0.94
22 June	7.0	79.6	3.07	0.87
Sum	4.7	83.6	0.09	0.96

[1] Intercept not significantly different from zero.

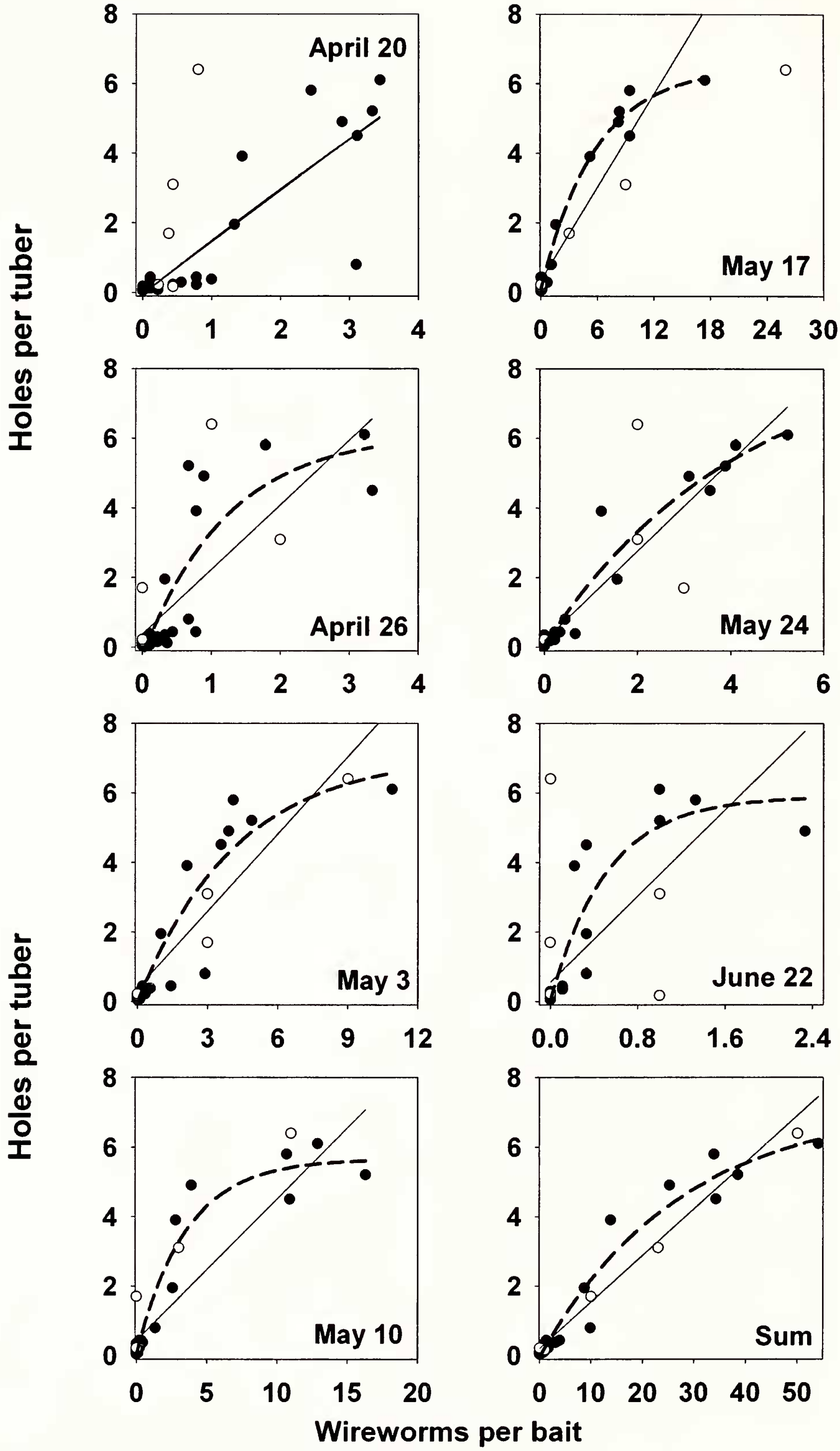

Figure 4. Scatter plots and regression lines showing relationship between number of wireworms per bait and number of holes per tuber. Solid circles: nine baits per plot (N = 25 plots); open circles: one bait per plot (N = 5 plots). Regressions fitted excluding the open symbols. Both linear and asymptote models are shown (regression lines overlap for the 20 April sample). "Sum": wireworm numbers per bait were summed over the seven sample weeks.

Table 2.
Regression statistics from linear and asymptote models relating wireworm counts per bait to number of holes per tuber. N = 25 observations per date.

	Linear model			Asymptote model			
	Intercept[1]	Slope	r^2	Intercept[1]	*a*	*b*	r^2
20 April	-0.04	1.48	0.75	-0.06	44.5	0.04	0.75
26 April	0.37	1.86	0.62	-0.29	6.4	0.82	0.73
3 May	0.37	0.74	0.75	-0.04	7.1	0.24	0.87
10 May	0.44	0.41	0.81	0.03	5.6	0.29	0.95
17 May	0.35	0.45	0.90	0.10	6.4	0.17	0.98
24 May	0.18	1.29	0.94	0.06	8.7	0.24	0.95
22 June	0.56	3.10	0.66	0.02	5.9	1.93	0.86
Sum	0.20	0.13	0.91	-0.05	7.3	0.04	0.96

[1] Intercepts significantly different from zero only for the 10 May and 17 May linear models

Table 3.
Predicted percentage of tubers damaged (from asymptote models in Figure 3 and Table 1) for different wireworm counts per bait provided for each sampling date. The shaded area encompasses predictions within the range of wireworm counts observed in the samples.

Wireworms	Pre-planting		Post-planting				
per bait	20 April	26 April	3 May	10 May	17 May	24 May	22 June
0	5	2	6	7	8	7	7
0.25	14	24	15	16	16	20	50
0.5	22	40	23	24	23	32	69
1.0	37	62	36	38	35	49	83
1.5	49	74	47	49	45	61	86
2.0	59	81	56	57	52	70	86
2.5	68	85	63	63	59	75	87
3.0	75	88	68	68	65	80	87
4.0	85	90	76	75	72	84	87
5.0	93	90	81	79	77	87	86
10.0	>100	91	91	85	84	89	86
15.0	>100	91	92	85	85	89	86

age are not known, but could include characteristics of the soil (soil type, moisture, organic matter) and availability of preferred host plants in previous growing seasons (Gui 1935, Lefko *et al.* 1998, Parker and Howard 2001). The row of plots having the highest densities of wireworms (Fig. 1A) occurred in an area of the field that had been planted to potatoes in each of the previous five years. The row of plots which had the lowest densities occurred in an area of the field that had in some preceding years been left fallow.

Tuber damage, expressed either as percent of tubers damaged or as number of holes per tuber, showed a curvilinear relationship with wireworm counts (Figs. 3-4). Curves exhibited a rapid increase in damage levels with increasing numbers of wireworms at lower wireworm numbers, while showing slower increases in damage with increasing wireworm numbers as

Table 4.

Sample date, soil temperature at 31 cm, number of soil cores sampled (n), total number of wireworms collected, and number of wireworms per soil core collected at each of three depths. Numbers in parentheses indicate percentage of total obtained at that depth. Data for the earliest dates have been combined due to difficulties finding wireworms.

Sample date	Soil temperature at 31 cm (°C)	n	Total wireworms collected	Number of wireworms per soil core (% of total)		
				0-31 cm	31-61 cm	61-91 cm
March 15 and 23	8.3	90	37	0.17 (41%)	0.14 (34%)	0.10 (24%)
March 31 and April 7	9.4	70	44	0.40 (64%)	0.17 (27%)	0.06 (9%)
April 15	9.4	30	42	0.70 (50%)	0.43 (31%)	0.27 (19%)
April 22	13.9	30	48	0.97 (61%)	0.50 (31%)	0.13 (8%)
April 28	15.0	30	51	0.90 (53%)	0.40 (24%)	0.40 (24%)
May 13	17.2	30	40	1.17 (88%)	0.17 (13%)	0.00 (0%)

wireworm counts became high. These results suggest that low densities of wireworms caused disproportionate levels of damage relative to levels of damage caused by high densities of the pest. It may be that tubers or feeding sites previously damaged by wireworms were attractive to other wireworms, and that wireworms at high densities tended to feed on the same tubers and in the same sites on those tubers that had been previously damaged by other wireworms. Gibson (1939), who used soil sifting rather than baiting to estimate densities of *Limonius* spp., also concluded that levels of damage caused by wireworms were disproportionately high at low densities of the pests.

Use of soil sampling to predict tuber damage has suffered from the occurrence of false negatives in the sampling results (Parker and Howard 2001). That is, wireworm densities below the level of detection may nonetheless cause economic damage to tubers (Parker and Howard 2001). The present study suggests that baiting may suffer from the same criticism. Three of the plots having the high density of baits failed to collect a single wireworm over the duration of the seven sample weeks. Tuber damage occurred in all three of these plots (3.3-6.8% of tubers were damaged in those plots). The presence of zero counts was observed despite use of an impractically (for growers) high density of baits. Regression models describing percentage tuber damage (Fig. 3, Table 1) often exhibited significant intercept terms, indicating that predicted damage was non-zero at wireworm counts of 0 per bait.

Counts of wireworms in baits were low in the pre-planting samples, increased to a peak just before plant emergence, and declined thereafter. The early season counts in baits may have been low in part because cool temperatures led to lowered rates of wireworm movement or feeding, or slowed spread of bait volatiles through the soil. The drop in wireworm counts between the first and second sample dates accompanied a period of cooling soil temperatures (Fig. 2). The drop in numbers following peak count may have been due in part to wireworms feeding on seed pieces and the developing potato plants, rather than on the baits. Toba and Turner (1981) demonstrated that counts of wireworms in seed pieces following planting could be used to predict end-of-the-season wireworm damage to potatoes, suggesting that wireworms feed readily on seed pieces.

Another factor possibly contributing to seasonal patterns in counts (Fig. 2) is that movement by wireworms into the baiting area, from overwintering quarters deeper in the soil, appears to occur over a fairly long time interval. Thus, in April, the low counts in baits may have been caused in part by the fact that a proportion of the population was relatively deep in the soil. The depth study in 2005 showed that 8-24% of wireworms collected between March and late-April were obtained at the 61-91 cm depth. Only as soil temperatures at 31 cm approached 17 °C (in the mid-May sample), did I fail to collect wireworms at the 61-91 cm depth. That soil temperature was not reached in the baiting study of the previous year until early May (Fig. 2), which was about two weeks after planting. The depth study was done in a fallow field. It is not known whether movement up the soil profile by wireworms in spring would have occurred more rapidly had there been a food source available (e.g., newly planted potato seed pieces).

One consequence of the week-to-week differences in wireworm counts is that predicted damage for a given count varied week-to-week. Three of the sampling dates on which overall counts were low (26 April, 24 May, and 22 June) produced damage predictions for a given bait count that were substantially higher than predictions obtained on those dates for which baiting efficiency was better (Table 3; for a given bait count, contrast predictions for the May 3, 10, and 17 dates with predictions from 26 April, 24 May, and 22 June). That is, because baiting efficiency varied seasonally (being comparatively inefficient during pre-planting and post-emergence samples relative to the May 3-17 samples; Fig. 2), a given wireworm count did not provide a constant estimate of damage potential among sample weeks. Consequently, regression models indicated that a given level of damage would be associated with lower bait counts during the pre-planting and post-emergence periods than during those three weeks in May when baiting was more efficient (Table 3). Thus, factors that cause reduced bait efficiency (e.g., wireworms deep in soil, low soil temperatures, or presence of competing food sources), would lead to overestimates of damage potential relative to estimates obtained for the same bait count when baiting was more efficient.

In summary, results suggest that using baits before planting potatoes to predict end-of-the-season damage to tubers would be difficult to implement with a great deal of confidence. First, the bait densities which were used in this study were much too high to be used feasibly by growers. Moreover, as baiting density was lowered, scatter of points around the regression lines appeared to increase (Figs. 3-4). Thus, use of a logistically more feasible bait density would result in a sacrifice of model fit. Second, predicted levels of damage for a given absolute density of wireworms depended on time of year and sampling efficiency (Table 3), thus it is not possible to develop a single, general regression model that would allow growers to predict damage from counts of wireworms in baits without taking into account factors (e.g., soil temperature, wireworm depth in the soil) that are likely to affect baiting efficiency. Finally, on the two pre-planting sampling dates, baits failed to collect even a single wireworm in over 25% of the plots. All of those plots nonetheless experienced end-of-the-season damage. Thus, potato growers who might use these baits to predict damage potential would have to accept the possibility that fields in which baits failed to detect wireworms could nonetheless experience some level of damage.

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